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# DESCRIPTION AND EVALUATION OF A FLUOROSCOPIC SCREEN VISUAL BRIGHTNESS COMPARER

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Public Health Service
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46

DIVISION OF ELECTRONIC PRODUCTS

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# DESCRIPTION AND EVALUATION OF A FLUOROSCOPIC SCREEN VISUAL BRIGHTNESS COMPARER

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March 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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John C. Villforth
Director
Bureau of Radiological Health

## PREFACE

It may be possible to reduce the population dose where old or inefficient fluoroscopic screens are in present use by replacing these screens with new ones. NCRP Report No. 33 advises checking the efficiency of a fluorescent screen by comparing it with a new screen. Mr. Emmet Murphy of the X-ray Exposure Control Laboratory has developed an instrument based on this comparison principle which makes it possible for an observer to visually determine the brightness of two fluoroscopic screens under field survey conditions.

A field test of this fluoroscopic screen Visual Brightness Comparer was conducted in New York City in cooperation with the New York City Department of Health, Office of Radiation Control. This report contains a description and evaluation of the instrument. The conclusion was reached that although it is theoretically possible to use a visual comparison technique for checking fluoroscopic screens, the technical problems associated with an instrument based on this principle drastically limit its use.

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Division of Electronic Products

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# DESCRIPTION AND EVALUATION OF A FLUOROSCOPIC SCREEN VISUAL BRIGHTNESS COMPARER

## INTRODUCTION

The luminescent response of a fluoroscopic screen for typical diagnostic exposure levels is a linear function. Properzio and Trout (1) showed that over the years there has been an improvement in the luminescent response of these screens due to the availability of new types of phosphors and technological advances in the manufacture of fluoroscopic screens. They show exposure factors, defined as the factor by which exposure rate must be increased for an old screen to obtain the same light output level as with a new screen, that vary from slightly greater than one to as great as ten for the screens they tested. Therefore, it may be possible to reduce the population dose by the replacement of these relatively inefficient screens with new ones. NCRP Report No. 33 (2) states:

> "If a fluoroscope meets the performance standards of this section but the fluoroscopist finds it necessary to operate the equipment routinely at exposure rates in excess of 5 R/min., it is advisable to check the efficiency of the fluorescent screen by comparing it with a new screen."

Blatz (3) also states:

> "A very important factor that is often overlooked is that the fluorescent screen should be a modern, highly sensitive screen .... It is shocking to find so many fluoroscopes in use today that have screens more than twenty years old. Since screens made today are at least twice as sensitive as those made over twenty years ago ...., patients examined with such fluoroscopes are receiving three to five times as much radiation as is necessary, and the images viewed on the screens lack the important detail that can be obtained only with a relatively new screen in good condition. This is particularly important since even under ideal conditions, the dose in fluoroscopy is very large."

Although the type of screen may limit the maximum light output, other factors such as phosphor deterioration, yellowing of the lead glass, and accumulation of dirt may affect luminescent efficiency. Therefore, the important factor to check is this luminescent response. The fluoroscopic screens must be checked on the equipment in which they are installed since the screens cannot be easily removed and might be subject to damage.

As a consequence, there is a need for a rugged, lightweight, field instrument which has the capability of measuring fluoroscopic screen brightness from which one may evaluate its performance against some "standard". Several instruments immediately come to mind. One is the ordinary hand-held photographic light meter. However, this instrument is inadequate for this application due to its lack of sensitivity at the extremely low light levels, approximately 0.01 millilambert, associated with fluoroscopic screen operation. There are various photometric devices which are sensitive and accurate but are unsuited for field testing due to their prohibitive high cost and bulkiness.

The design and construction of an instrument which makes it possible to simultaneously view the light output of a test screen and a "standard" screen so that an observer can visually compare the brightness of the two was undertaken.

Two important factors must be considered in the evaluation of an instrument of this type. The first is the subjectivity of the test. The judgement of one observer does not necessarily match that of another. The second is the limited ability of the human eye to discriminate between differences in brightness at these low light levels. As shown by Chamberlain (4) figure 1, the human eye is incapable of discriminating between brightnesses that are less than 5-10 percent apart at the levels experienced in conventional fluoroscopy. It is, of course, possible to increase the brightness sensitivity of the eye by dark adapting. However, isolation in a darkened environment or the use of red goggles may not be practical in a field situation. Despite these limitations, an evaluation of the device was conducted. The evaluation consisted of a series of laboratory tests (described in appendix B,) followed by a field test.

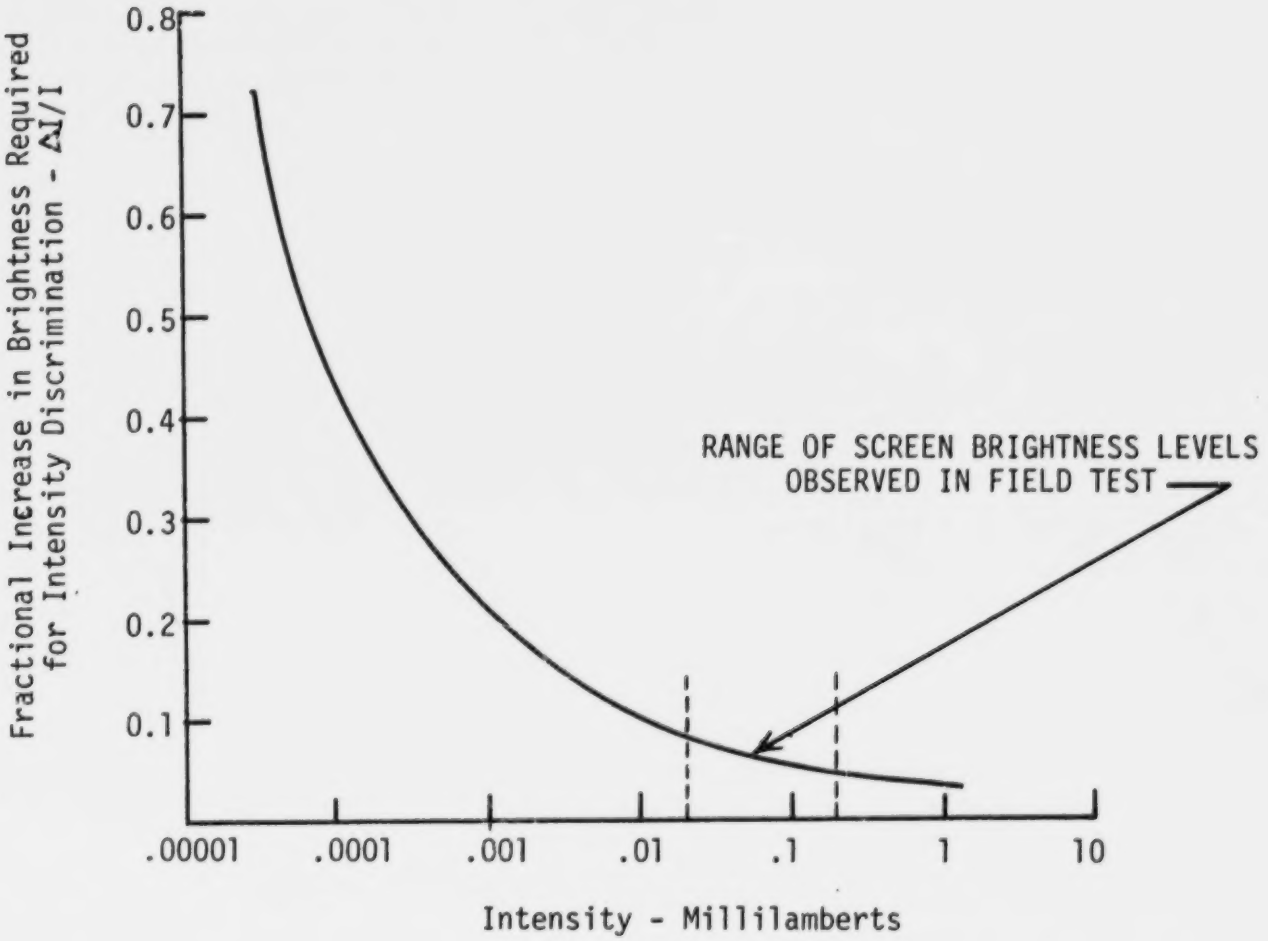


Figure 1. Intensity discrimination ($\Delta$ I/I) as a function of brightness (4)

## DESCRIPTION OF VISUAL BRIGHTNESS COMPARER

Mr. Emmet Murphy of the X-ray Exposure Control Laboratory designed an instrument which is inexpensive, rugged, lightweight, and simple to use (figures 2, 3, 4).

The Visual Brightness Comparer is used as follows:

A fluoroscopic screen under test and a "standard" fluoroscopic screen (a new Radelin FGC) are simultaneously irradiated. The light produced by the two screens is projected by an arrangement of mirrors to a viewing port. The light output from both screens is observed simultaneously, with the light from the test screen occupying the peripheral portion of the viewing area and the light from the "standard screen occupying the central portion. The observer is required to make a determination of comparative screen brightness. Through a series of comparisons between the test screen and the "standard" screen plus a number of substitution screens (screens whose relative luminescent efficiencies[1] are calibrated in relation to the "standard" screen) of known, but varying brightnesses, the observer can obtain an approximate measurement of the test screen brightness.

The Visual Brightness Comparer, consisting of two connected tubes, is positioned during a test with one tube hanging in front of the fluoroscopic screen assembly and the other hanging behind the fluoroscopic screen assembly (see figure 2). The bottom end of the front tube has a 1-5/8 inch x 1-3/8 inch opening which allows X-rays to enter, with no attenuation, and strike a "standard" fluoroscopic screen or substitution screen. The light produced by this screen is collected by a mirror situated at the bottom of the front tube and at a 20° angle to the fluoroscopic screen so that a major portion of the light is reflected up the tube. At the top of the front tube is another mirror which reflects the light coming up the tube to a viewing port. The tube that hangs behind the fluoroscopic screen assembly has a 1-5/8 inch x 1-3/8 inch opening which allows the light produced by the test screen in the fluoroscopic screen assembly to enter the tube. This light is then directed to the viewing port by a mirror located at the bottom of the tube and positioned at a 45° angle to the incoming light.

The viewing port (see figures 3 and 4) consists of a partial mirror situated at the top of the rear tube at a 45° angle to the light directed up the rear tube. This light is then projected forward to the viewer's eye through a 1-1/2 inch diameter circle cut out of the back end of the tube.

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[1] For the purpose of this report the relative luminescent efficiency of any screen is defined as the ratio of a photometer reading of the screen to the photometer reading of a new Radelin FGC screen, whose relative luminescent efficiency is arbitrarily defined as one, when measured under the same conditions.

Figure 2. Visual Brightness Comparer with substitution screens

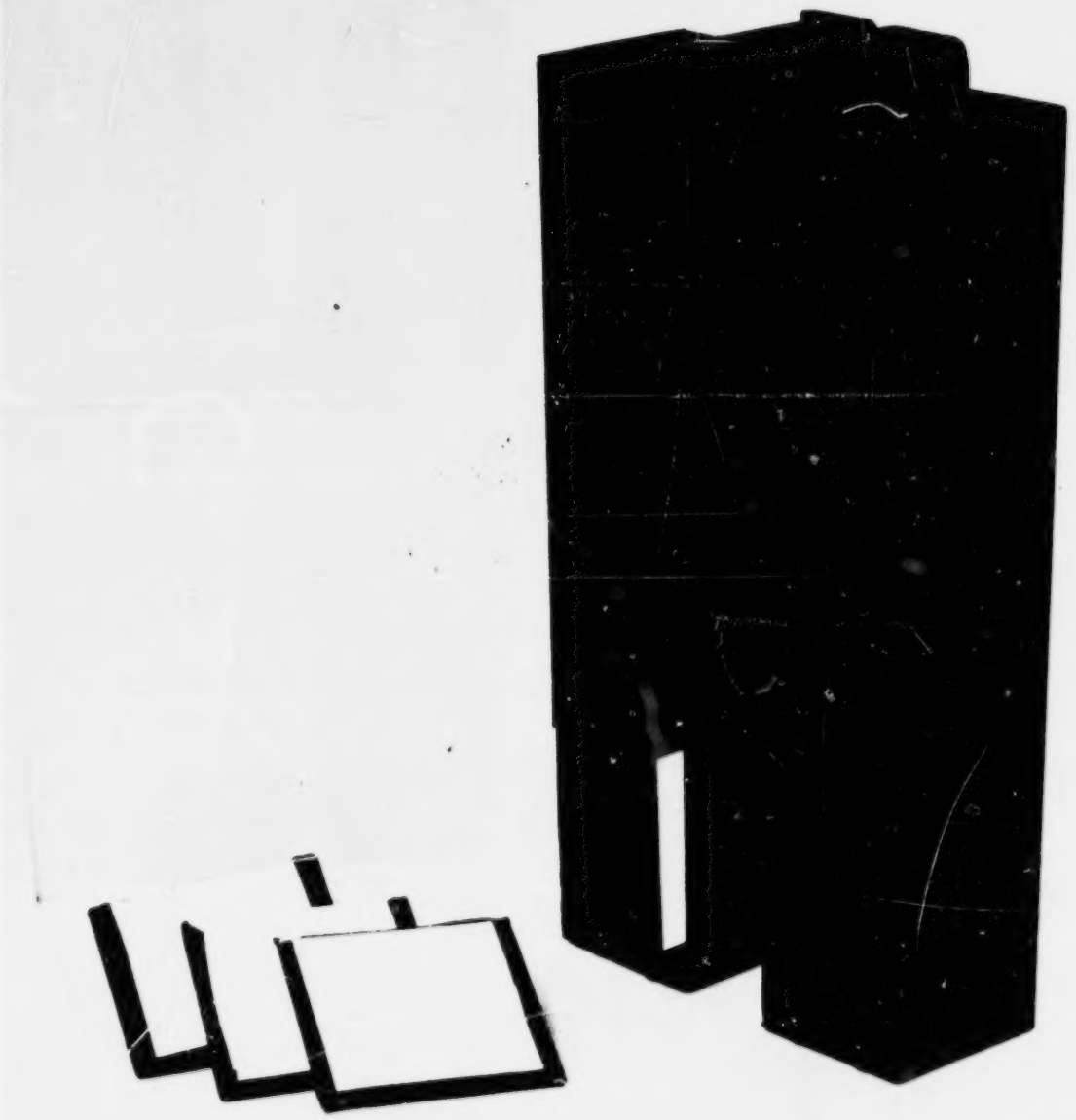



Figure 3. Visual Brightness Comparer showing viewing port

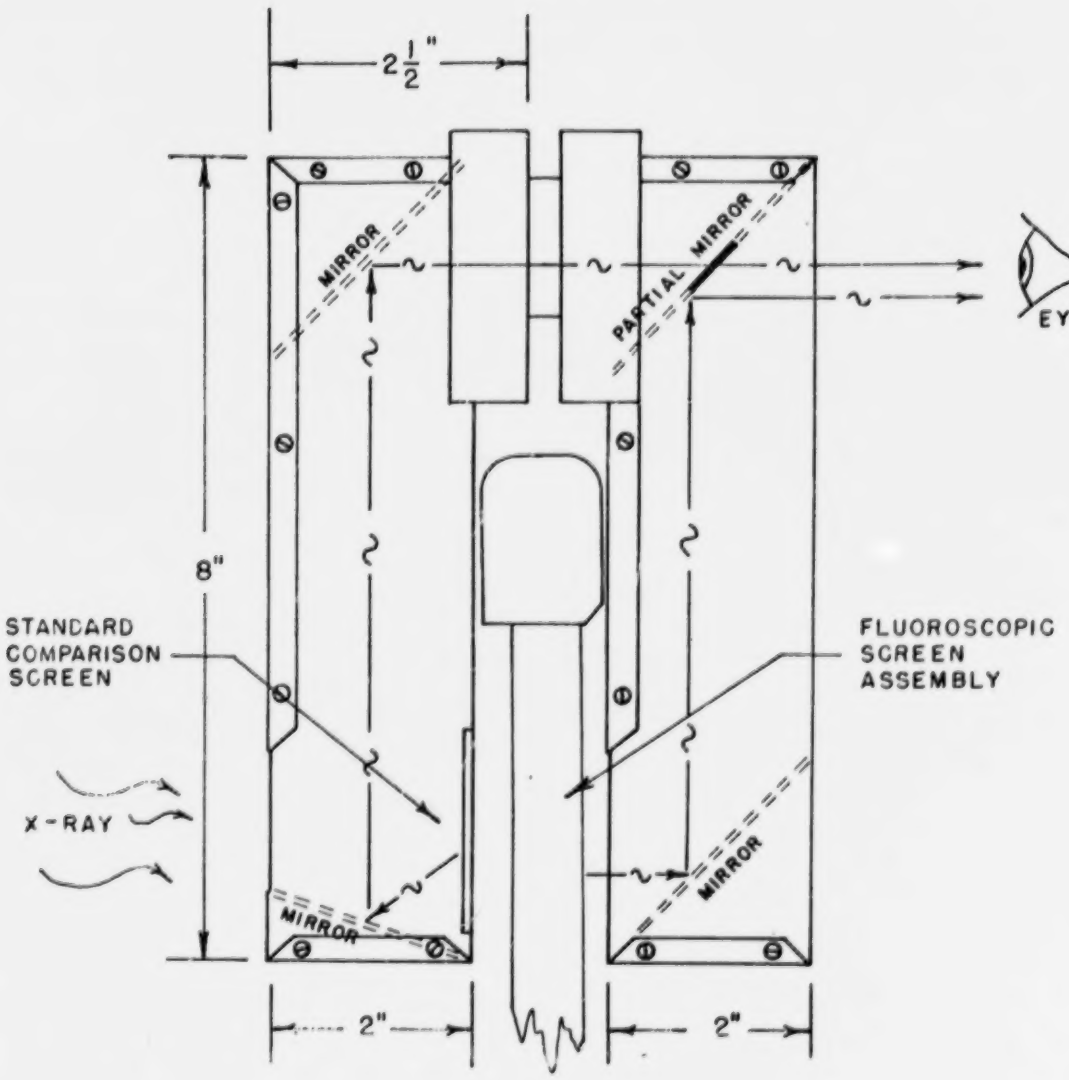



Figure 4. Visual Brightness Comparer schematic

The silver backing of the mirror in the viewing port is removed in a small area around the center so that the light reflected from the front tube is allowed to pass through in this area and the light from the rear tube is not reflected to the viewer in this area. Therefore, the viewer sees only the light produced by the "standard" screen or substitution screen in the central portion of the viewing port, and only the light produced by the test screen in the peripheral portion of the viewing port.

During operation, the front tube of the comparer is slightly cocked to the right (see figure 2) so that the X-ray beam irradiating the test screen is not attenuated. Also, the length of the coupling between the front and rear tube is variable, between 3/4 inch and 1-1/4 inch, to allow for variation in size of the fluoroscopic screen assembly.

## FIELD TEST

A field test of the fluoroscopic screen Visual Brightness Comparer was conducted in New York City in conjunction with the New York City Department of Health, Office of Radiation Control. Thirty-one screens were examined; one in the laboratory of the Office of Radiation Control, eight in hospitals, and twenty-two in doctors' private offices.

One of the factors that must be considered when using a visual comparison technique is the ability of the eye to correctly categorize differences in brightness levels. This ability will vary slightly from one observer to another, but it was felt that the field test would give an indication of what accuracy might be expected of a comparison technique under actual survey conditions. To provide a basis for comparison, the photometer described in the appendix was used in conjunction with the Visual Brightness Comparer in all screen surveys.

The actual field survey procedure involved independent determinations of the screens performance with the photometer and the Visual Brightness Comparer. A 6-inch x 6-inch X-ray field was first established at a distance of 10 inches from the tabletop or fluoroscopic machine panel. At this distance a photometer reading from the "standard" screen assembly (see appendix C) was obtained. The photometer reading of the test screen was obtained by positioning the test screen assembly 10 inches from the panel and tightly holding the photometer head against the screen while the screen was being irradiated. The X-ray machine mA and kVp settings were held constant for both readings. When possible, the tests were made at 70 kVp and 3 mA. In many cases this could not be done because the machine settings were limited to LOW, MEDIUM, and HIGH or some other type of non-calibrated settings. In these instances settings were chosen to approximate the 70 kVp and 3 mA values.

The radiation output of many of the fluoroscopic machines encountered during the field test was observed to vary considerably during operation; therefore, it was necessary to monitor the X-ray output of the machine while the photometer readings of the test screen and "standard" screen were being obtained. The photometer reading of the test screen was then corrected if necessary by a factor which normalized the exposure rate taken during the photometer reading of the test screen to the exposure rate taken during the photometer reading of the "standard" screen. The exposure rates were determined by placing a five-roentgen Victoreen condenser-R chamber (Model 570) in the X-ray beam for fifteen seconds while each photometer reading was being obtained. For purposes of this report, the ratio of the normalized photometer reading of the test screen to the photometer reading of the "standard" screen is considered to be the relative luminescent efficiency of the test screen.

Two observers next independently determined the relative luminescent efficiency of a test screen with the Visual Brightness Comparer by comparing the test screen with a "standard" screen. If the test screen was judged less efficient than the "standard", the "standard" screen was removed from the comparer and replaced by a substitution screen whose relative luminescent efficiency was a known value less than the "standard". The test screen was then compared with the substitution screen and another judgement made. By repeating this process as often as was necessary the relative luminescent efficiency of the test screen was bracketed between the known relative luminescent efficiencies of two screens.

The "standard", whose relative luminescent efficiency was defined as one, was a new Radelin FGC. Laboratory measurements of the substitution screens resulted in the following relative luminescent efficiencies: 0.95, 0.85, 0.80, 0.70, and 0.55.

The accuracy of the Visual Brightness Comparer was determined by correlating the relative luminescent efficiencies of the test screens obtained with the comparer against the relative luminescent efficiencies of the same screens obtained with the photometer.

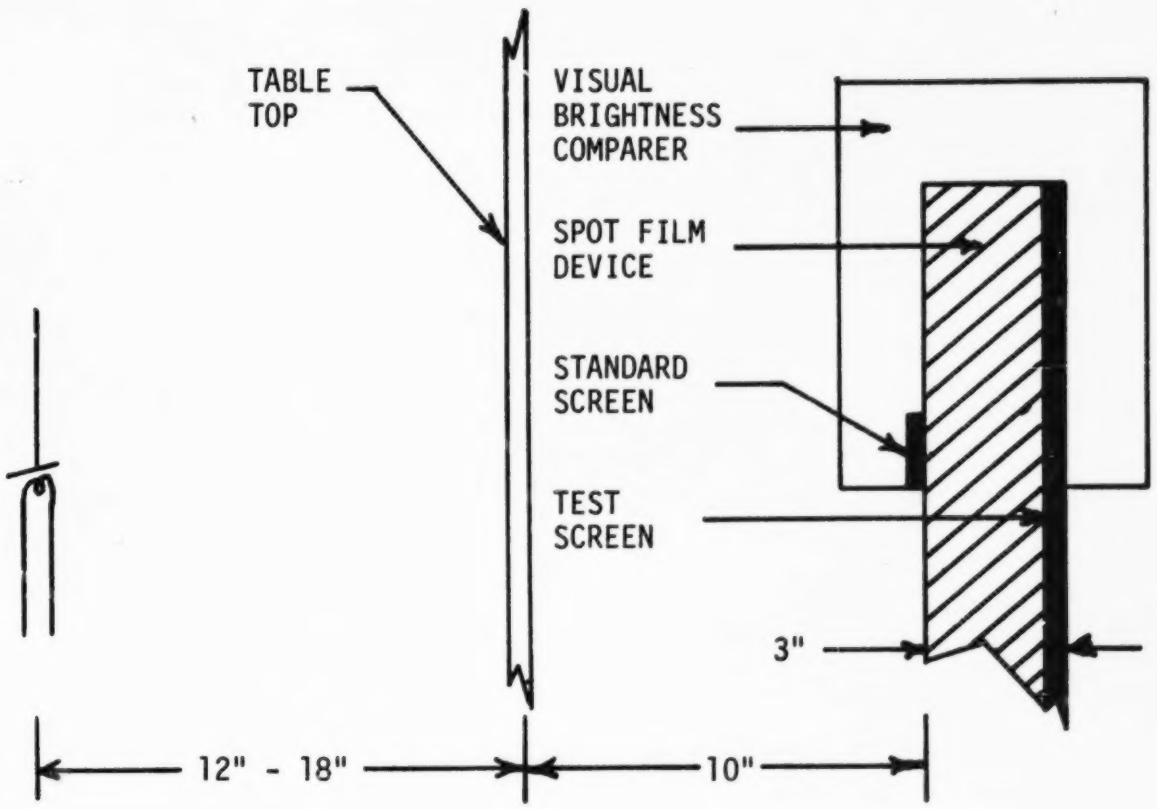
## ANALYSIS OF FIELD TEST DATA

### Qualitative

One of the major difficulties encountered was caused by color differences between the "standard" screen or substitution screens, and the test screen. Often it was difficult to make a judgment with regard to brightness when this color difference was observed. The "standard" screen had a distinct green hue, whereas many of the test screens were yellow in color. Ideally it would be desired that when judging brightness difference between the two screens, there would be no color difference to affect the judgment. The use of colored filters might be one solution to this problem, but the problem of selecting an appropriate filter to compensate for all possible color difference that might be found in different screens would be very difficult. Another disadvantage in the use of filters in a device of this type is the problem of signal attenuation. With these considerations in mind, it does not seem practical to try to compensate for color differences in the screen.

During the field test, it became evident that the repeated process of manually changing the "standard" screen and substitution screens was inconvenient and sometimes awkward. One suggested remedy is to install a rotor-type device behind the partial mirror in the viewing port with pie-shaped wedges made of neutral density filters. Using this device it would only be necessary to rotate a filter in place so that the screen could be compared with a screen whose relative luminescent efficiency was a known value less than the "standard" screen. This would eliminate the need for calibrated substitution screens.

In its present form the Visual Brightness Comparer cannot be used on fluoroscopic assemblies that are equipped with a spot-film device. Mechanically, this problem could be solved by lengthening the pipe coupling the two halves of the comparer. However, two problems arise. The first results from the fact that the intensity of the radiation decreases as the square of the distance from the X-ray source. For typical survey conditions that provide reasonably high brightness levels suitable for visual measurements (see figure 5) the "standard" screen would receive about twenty percent more radiation than the test screen, and, consequently, the "standard" screen would appear at least 20 percent brighter. Secondly, the spot-film device attenuates and scatters the X-ray beam. There is no way to predict the extent of the error caused by these effects for every spot-film device, and, therefore, compensation would be difficult.




A. TARGET TO TABLE TOP DISTANCE: 12"

$$\frac{\text{Intensity at Test Screen}}{\text{Intensity at Standard Screen}} = \frac{22^2}{25^2} = 0.78, \text{ 22\% Difference}$$

B. TARGET TO TABLE TOP DISTANCE: 18"

$$\frac{\text{Intensity at Test Screen}}{\text{Intensity at Standard Screen}} = \frac{28^2}{31^2} = 0.81, \text{ 19\% Difference}$$

Figure 5. Effect of spot film device on Visual Brightness Comparer readings of two geometries

Quantitative

The data obtained during the field test are summarized in tables 1-4. Table 1 lists the distribution of fluoroscopic screens, and table 2 the distribution of X-ray machines by manufacturer, encountered during the field test. The relative luminescent efficiencies of the test screens, determined with the photometer, are presented in table 3. Table 4 shows a direct comparison of the relative luminescent efficiencies of the test screens obtained with the photometer and with the Visual Brightness Comparer.

The relative luminescent efficiency of a test screen obtained with the photometer is determined by computing the ratio of the corrected photometer reading of the test screen to the photometer reading of the "standard" screen. The photometer reading of the test screen had to be adjusted, as was mentioned in the Field Test section, to account for the difference in exposure rates due to X-ray machine variation. The formula used for the adjustment was:

$$\text{Corrected photometer reading} = \frac{\text{Exposure rate during reading of "standard" screen}}{\text{Exposure rate during reading of test screen}} \times \text{Photometer reading of test screen}$$

This correction is valid since the photometer responds linearly as the exposure rate to the fluoroscopic screen is increased.

It should be noted that since the photometer has a continuous scale, the calculated relative luminescent efficiency of a test screen obtained from the photometer measurements may be any continuous value greater than or equal to zero. However, since the comparer uses "standard" and substitution screens of discrete relative luminescent efficiencies, its measurement of the relative luminescent efficiency of a test screen was limited to the following discrete values: 1.0, 0.95, 0.85, 0.70, and 0.55. Since the Visual Brightness Comparer measurements were limited to discrete values ranging from 1.00 to 0.55, a percent difference from the photometer values could only be obtained for those test screens whose relative luminescent efficiencies were in this range. There were four screens whose relative luminescent efficiencies were greater than 1.00 and seven screens whose relative luminescent efficiencies were less than 0.55. For these screens the percent differences were calculated by assuming the relative luminescent efficiencies to be 1.00 and 0.55 respectively. The percent differences were rounded to the nearest five percent.

Table 1. Distribution of fluoroscopic screens encountered during field test

| Screen Types | Number |
|---|---|
| Unknown | 11 |
| Patterson B | 6 |
| Patterson B-2 | 6 |
| Radelin FG | 4 |
| DuPont CB-2 | 3 |
| Ultraphan | 1 |

Table 2. Distribution of X-ray machines by manufacturer, encountered during field test

| Machine Manufacturers | Number |
|---|---|
| Picker | 11 |
| North American Philips | 6 |
| Mattern | 4 |
| Continental | 2 |
| Wappler | 2 |
| Standard | 1 |
| Keleket | 1 |
| Koenitz | 1 |
| Universal | 1 |
| Profex | 1 |
| Peerless | 1 |

Table 3. Relative luminescent efficiencies of test screens measured with the photometer

| Index Number | STANDARD SCREEN | | TEST SCREEN | | | |
|---|---|---|---|---|---|---|
| | Photometer Reading | Exposure Rate During Reading (R/min) | Photometer Reading | Exposure Rate During Reading (R/min) | Normalized Photometer Reading | Relative Luminescent Efficiency |
| 1 | 52 | 1.15 | 57 | 0.96 | 68 | 1.30 |
| 2 | 90 | 1.76 | 85 | 1.60 | 93 | 1.03 |
| 3 | 58 | 1.36 | 60 | 1.36 | 60 | 1.03 |
| 4 | 83 | 1.40 | 85 | 1.40 | 85 | 1.02 |
| 5 | 130 | 2.40 | 125 | 2.40 | 125 | 0.96 |
| 6 | 55 | 1.00 | 54 | 1.08 | 50 | 0.91 |
| 7 | 66 | 1.80 | 60 | 1.80 | 60 | 0.91 |
| 8 | 155 | 2.60 | 125 | 2.30 | 141 | 0.91 |
| 9 | 105 | 2.10 | 95 | 2.10 | 95 | 0.90 |
| 10 | 125 | 2.20 | 130 | 2.64 | 109 | 0.87 |
| 11 | 77 | 1.50 | 67 | 1.50 | 67 | 0.87 |
| 12 | 212 | 4.20 | 185 | 4.40 | 177 | 0.84 |
| 13 | 80 | 1.80 | 65 | 1.80 | 65 | 0.81 |
| 14 | 65 | 0.96 | 65 | 1.20 | 52 | 0.80 |

Table 3. (continued)

| Index Number | STANDARD SCREEN | | TEST SCREEN | | | |
|---|---|---|---|---|---|---|
| | Photometer Reading | Exposure Rate During Reading (R/min) | Photometer Reading | Exposure Rate During Reading (R/min) | Normalized Photometer Reading | Relative Luminescent Efficiency |
| 15 | 105 | 2.16 | 75 | 1.92 | 84 | 0.78 |
| 16 | 43 | 0.80 | 33 | 0.80 | 33 | 0.77 |
| 17 | 125 | 2.40 | 103 | 2.60 | 95 | 0.76 |
| 18 | 82 | 1.60 | 76 | 2.00 | 61 | 0.74 |
| 19 | 74 | 1.52 | 54 | 1.52 | 54 | 0.73 |
| 20 | 57 | 1.20 | 47 | 1.36 | 41 | 0.72 |
| 21 | 115 | 2.60 | 70 | 2.56 | 71 | 0.62 |
| 22 | 95 | 2.10 | 52 | 1.90 | 57 | 0.60 |
| 23 | 170 | 3.40 | 97 | 3.40 | 97 | 0.57 |
| 24 | 55 | 1.12 | 30 | 1.12 | 30 | 0.55 |
| 25 | 97 | 2.00 | 60 | 2.30 | 52 | 0.54 |
| 26 | 82 | 1.68 | 50 | 1.90 | 44 | 0.54 |
| 27 | 80 | 1.28 | 50 | 1.52 | 42 | 0.53 |
| 28 | 197 | 4.00 | 100 | 4.00 | 100 | 0.51 |
| 29 | 205 | 5.10 | 95 | 4.80 | 101 | 0.49 |
| 30 | 115 | 2.40 | 52 | 2.40 | 52 | 0.45 |
| 31 | 85 | 1.60 | 42 | 2.00 | 34 | 0.40 |

Table 4. Percent difference between the relative luminescent efficiencies of the test screens measured with the photometer and measured with the Visual Brightness Comparer

| Index Number | Screen Type | Relative Luminescent Efficiency of Test Screen (Photometer)* | Observer #1 | | Observer #2 | |
|---|---|---|---|---|---|---|
| | | | Relative Luminescent Efficiency of Test Screen (Comparer) | Percent Difference | Relative Luminescent Efficiency of Test Screen (Comparer) | Percent Difference |
| 1 | Ultraphan | > 1.00 | 1.00 | 0% | 1.00 | 0% |
| 2 | Rad FGC | > 1.00 | 1.00 | 0% | 1.00 | 0% |
| 3 | Unknown | > 1.00 | 1.00-0.95 | -5% | 1.00 | 0% |
| 4 | Unknown | > 1.00 | 1.00 | 0% | 1.00-0.95 | -5% |
| 5 | CB-2 | 0.96 | 1.00-0.95 | 0% | 1.00 | +5% |
| 6 | Rad FGP | 0.91 | 1.00 | +10% | 1.00 | +10% |
| 7 | Unknown | 0.91 | 0.95 | +5% | 0.85 | -5% |
| 8 | B-2 | 0.91 | 1.00-0.95 | +10% | 0.95 | +5% |
| 9 | Unknown | 0.90 | 0.95 | +5% | 0.95 | +5% |
| 10 | CB-2 | 0.87 | 1.00-0.85 | +5% | 0.95-0.85 | 0% |
| 11 | Rad FG | 0.87 | 1.00-0.95 | +10% | 0.95-0.85 | 0% |
| 12 | CB-2 | 0.84 | 0.85-0.80 | 0% | 0.95-0.80 | +5% |

Table 4. (continued)

| Index Number | Screen Type | Relative Luminescent Efficiency of Test Screen (Photometer)* | Observer #1 | | Observer #2 | |
|---|---|---|---|---|---|---|
| | | | Relative Luminescent Efficiency of Test Screen (Comparer) | Percent Difference | Relative Luminescent Efficiency of Test Screen (Comparer) | Percent Difference |
| 13 | B-2 | 0.81 | 0.80 | 0% | 0.70 | -10% |
| 14 | Rad FG | 0.80 | 1.00-0.95 | +20% | 1.00 | +25% |
| 15 | Unknown | 0.78 | 1.00-0.95 | +25% | 0.95 | +25% |
| 16 | B-2 | 0.77 | 0.70 | -5% | 0.85 | +15% |
| 17 | B-2 | 0.76 | 0.95 | +25% | 0.95 | +25% |
| 18 | B-2 | 0.74 | 0.80-0.70 | 0% | 0.80-0.70 | 0% |
| 19 | B | 0.73 | $<0.55$ | -25% | 0.55 | -25% |
| 20 | B-2 | 0.72 | 0.55 | -25% | 0.70-0.55 | -15% |
| 21 | Unknown | 0.62 | 0.55 | -10% | 0.55 | -10% |
| 22 | Unknown | 0.60 | 0.70-0.55 | 0% | 0.55 | -10% |
| 23 | B | 0.57 | 0.55 | 0% | 0.55 | 0% |
| 24 | Unknown | 0.55 | 0.70-0.55 | +10% | 0.70-0.55 | +10% |

Table 4. (continued)

| Index Number | Screen Type | Relative Luminescent Efficiency of Test Screen (Photometer)* | Observer #1 | | Observer #2 | |
|---|---|---|---|---|---|---|
| | | | Relative Luminescent Efficiency of Test Screen (Comparer) | Percent Difference | Relative Luminescent Efficiency of Test Screen (Comparer) | Percent Difference |
| 25 | Unknown | 0.55 | 0.55 | 0% | 0.55 | 0% |
| 26 | Unknown | 0.55 | 0.70 | +25% | 0.70-0.55 | +15% |
| 27 | B | 0.55 | 0.55 | 0% | 0.70-0.55 | +15% |
| 28 | B | 0.55 | 0.55 | 0% | 0.55 | 0% |
| 29 | B | 0.55 | 0.55 | 0% | 0.55 | 0% |
| 30 | B | 0.55 | 0.55 | 0% | 0.55 | 0% |
| 31 | Liasar (?) | 0.55 | 0.55 | 0% | 0.55 | 0% |

* Values from Table 3

Analysis of the field test data shows that the Visual Brightness Comparer results correlate to within ± 10 percent of the photometer results for test screens having a relative luminescent efficiency between 1.00 and 0.80. However, for test screens whose relative luminescent efficiencies were between 0.80 and 0.60 the correlation between the comparer results and the photometer results declined to about ± 25 percent. For test screens whose relative luminescent efficiencies were less than 0.60, the Visual Brightness Comparer result and the photometer result correlate reasonably well, with the relative luminescent efficiencies measured with the comparer being from 0 to 15 percent higher (in one instance 25 percent higher) than the relative luminescent efficiencies measured with the photometer.

More important than merely determining the percent accuracy of the Visual Brightness Comparer is determining whether the comparer can do the job that it was designed for. That is, it is necessary to know to what extent the comparer can categorize fluoroscopic screens according to their relative luminescent efficiency and select out those screens which are of "poor" quality. For purposes of discussion, a "good" quality screen is arbitrarily defined as having a relative luminescent efficiency between 1.00 and 0.80, an intermediate screen is defined as having a relative luminescent efficiency between 0.80 and 0.60, and a "poor" quality screen is defined as having a relative luminescent efficiency less than 0.60. During the field test, 13 "good" screens, 8 "intermediate" screens and 10 "poor" screens were encountered according to measurements made with the photometer.

As can be seen in table 5, one observer using the Visual Brightness Comparer identified 80 percent of the "poor" screens, while the second observer using the comparer identified 70 percent of the "poor" screens. Consequently, 20 to 30 percent of the "poor" screens escaped identification. Furthermore, both observers classified 37.5 percent of the "intermediate" screens, presumably screens which need not be replaced, as being "poor" quality screens. The percentage of "poor" screens that cannot be identified and the percentage of "good" or "intermediate" screens that are incorrectly classified as "poor" screens will vary the arbitrary values of relative luminescent efficiency used to classify screens. However, it is clear that with an instrument with the limited accuracy of the Visual Brightness Comparer, a significant percent of the "poor" quality screens will escape identification, and a significant percent of the "good" or "intermediate" quality screens will be incorrectly classified.

Table 5. Classification of screens with Visual Brightness Comparer

| Photometer Classification of Screens | Comparer Classification of Screens | | | | | |
|---|---|---|---|---|---|---|
| | Observer Number 1 | | | Observer Number 2 | | |
| | "Good" | "Intermediate" | "Poor" | "Good" | "Intermediate" | "Poor" |
| "Good" (13 screens) | 100% | 0% | 0% | 92% | 8% | 0% |
| "Intermediate" (8 screens) | 37.5% | 25% | 37.5% | 50% | 12.5% | 37.5% |
| "Poor" (10 screens) | 0% | 20% | 80% | 0% | 30% | 70% |

## CONCLUSIONS

It has been shown that a reduction in radiation exposure can be achieved by replacement of Patterson B or older fluoroscopic screens with new screens. Screens that have undergone phosphor deterioration should also be replaced. In certain cases identification of these old screens can be made by noting the manufacturers designation on the screen. When this designation is not visible or when phosphor deterioration has occurred, it is necessary to have an instrument to aid survey personnel in this identification.

The Visual Brightness Comparer described in this report utilizes the principle of visual comparison suggested by NCRP Report No. 33. Analysis of the field test data shows that this comparer can categorize fluoroscopic screen luminescent levels to within 25 percent. This degree of accuracy is sufficient to allow the surveyor to initially classify fluoroscopic screens into two categories: "good" or probably "poor". However, the subjective nature of obtaining this information may often require verification with a more accurate instrument, thus requiring duplication of equipment. A number of technical limitations associated with this instrument have also been pointed out by our tests. In particular, the comparer is useful only in checking screen assemblies that do not have the thickness usually associated with a spot film device. Also, the use of the comparer with one "standard" screen and a number of substitution screens is not practical if any substantial number of these devices were to be constructed. There is no problem in obtaining the new "standard" screen, but obtaining any number of old screens of varying efficiency for use as substitutions would be impossible. It may be feasible to use neutral density filters with the "standard" screen to attenuate its luminescent output by a known amount, but this modification has not been attempted.

The conclusion is made that although theoretically the principle of employing a visual comparison technique could be used for checking fluoroscopic screens, the technical problems associated with an instrument based on this principle drastically limits its use. A more useful approach would be to use a photometer type instrument from which a meter reading could be obtained. The photometer we used in this study was of an older design employing a photomultiplier tube and battery high voltage supply. For field survey use this instrument would probably be considered too heavy. A smaller device containing modern electronic components could be developed and would be the recommended approach.

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# APPENDIX A

## EXPOSURE POTENTIAL TO SURVEY PERSONNEL

Measurements were made to estimate the exposure levels a person would be subjected to when using the Visual Brightness Comparer. The operation of the X-ray machine when making survey measurements is similar to a normal fluoroscopic exam except for the absence of the patient from the beam. The removal of the patient will reduce scatter around the screen assembly, and since normal survey procedure calls for the surveyer to wear a lead apron, exposure levels to critical areas covered by the apron may be less than that experienced by the radiologist under normal fluoroscopic operation.

The head represents the only portion of the body that may receive higher levels of exposure. There are four general areas around the comparer where exposure to the upper portion of the head may occur. These are shown in figure 6. The results of measurements at these points are shown in table 6.

Field tests indicate that an average of 1 minute of X-ray on time is sufficient for measurement with the Visual Brightness Comparer. For intermittent use of the device under these conditions the exposure levels seem reasonable. If extensive use were envisioned, the simple addition of a sheet of shielding material attached to the comparer and extending above the fluoroscopic screen assembly could be added. Consideration was also given to the possibility of redesigning the comparer in order to place the viewing port in a position so that the head of the observer is protected by the shielding of the lead glass. The difficulties involved did not seem worthwhile so no redesign was attempted.

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Table 6. Exposure rates measured at specified positions

| Exposure Position | Measured Exposure Rate |
|---|---|
| A | 5.0 mR/min |
| B | 1.5 mR/min |
| C | 6.0 mR/min |
| D | 1.0 mR/min |

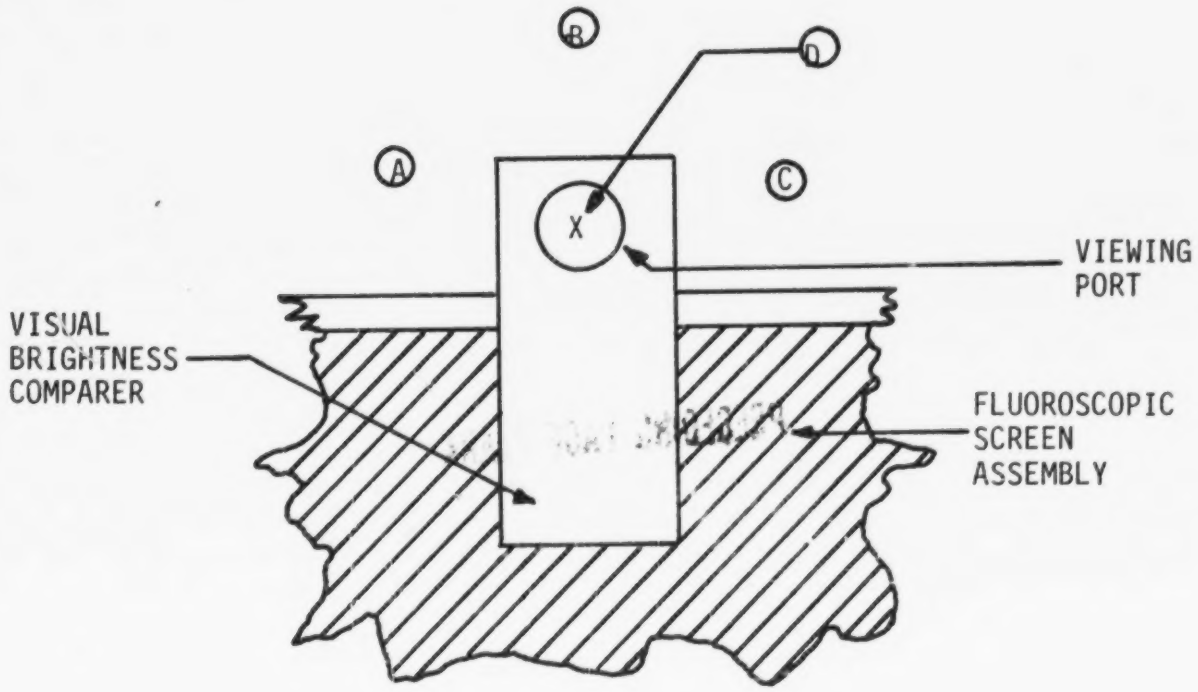


Figure 6. Positions monitored for exposure potential to survey personnel

# APPENDIX B

## LABORATORY TESTS OF THE VISUAL BRIGHTNESS COMPARER

Prior to the field test of the Visual Brightness Comparer, two laboratory tests were performed. The objectives of the first test were to determine the extent of brightness discrimination possible when using the comparer and to determine whether or not dark adapting significantly increased brightness discrimination. A second test was performed to determine the error in observer's estimates of the relative luminescent efficiency of an unknown screen when using the comparer, and to see if dark adapting significantly reduced the error. In each of these tests, the X-ray machine was operated at 80 kVp and 3 mA with 3 mm of aluminum filtration added. The beam had a measured half value layer of 2.5 mm of aluminum. The X-ray source to fluoroscopic screen assembly distance was 30 inches with a 1/8 inch piece of masonite board mounted at 20 inches from the source to simulate the X-ray machine table top. The beam covered a 5 inch x 5 inch area at the fluoroscopic screen.

In the first test, each of five observers used the Visual Brightness Comparer to determine if a difference in brightness existed between a test screen and nine substitution screens whose relative luminescent efficiencies were unknown to the observers. The test screen was a new Radelin FGC with a relative luminescent efficiency of 1.00. Two of the substitution screens had the same relative luminescent efficiency as the test screen, while the remaining screens had the following relative luminescent efficiencies: 0.95, 0.90, 0.85, 0.80, 0.70, 0.60, and 0.55. Each observer was given the comparer with the nine substitution screens and asked to place each in the comparer and make one of three responses; test screen brighter, substitution screen brighter, or no difference in brightness. In this way it was possible to determine the accuracy which a number of observers could detect the brightness difference between screens that are, for example, 40 percent different in brightness, or 20 percent, or even 5 percent. The nine substitution screens were used in a random order. The five observers compared the screens in a non-dark adapted condition. After an interval of one day each observer repeated the comparisons after dark adapting for twenty minutes. The results of the test are given in table 7.

Table 7. Accuracy of brightness discrimination of five observers using the Visual Brightness Comparer

| Relative Luminescent Efficiency of Substitution Screen | No dark adaption (5 observers) | | 20 min. dark adaption (5 observers) | |
|---|---|---|---|---|
| | No. of Observers Making Correct Response | Percent Verif-ication | No. of Observers Making Correct Response | Percent Verif-ication |
| 1.00 | 5 | 100% | 4 | 80% |
| 1.00 | 4 | 80% | 4 | 80% |
| 0.95 | 3 | 60% | 1 | 20% |
| 0.90 | 2 | 40% | 1 | 20% |
| 0.85 | 4 | 80% | 2 | 40% |
| 0.80 | 5 | 100% | 4 | 80% |
| 0.70 | 5 | 100% | 4 | 80% |
| 0.60 | 5 | 100% | 5 | 100% |
| 0.55 | 5 | 100% | 5 | 100% |

The second laboratory test was similar to the first. However, in this test the five observers were supplied with six substitution screens whose relative luminescent efficiencies were known to them, and asked to estimate the unknown relative luminescent efficiency of a test screen with the Visual Brightness Comparer. The first known fluoroscopic screen was a new Radelin FGC with a relative luminescent efficiency of 1.00, while the other five known screens had the following relative luminescent efficiencies: 0.95, 0.85, 0.75, 0.70, and 0.60. The unknown test screen had a relative luminescent efficiency of 0.80. The procedure that the observers used was the same procedure used in the field test. That is, an observer would determine if the unknown screen was as bright as the new Radelin FGC. If the observer thought the unknown was less efficient than the Radelin FGC, he would try to determine the efficiency by successive comparisons with the substitution screens. The estimates of the unknown screen's efficiency were made by the observers with and without dark adaption. In table 8 the percent error in the observers' estimates of the relative luminescent efficiency of the unknown is presented.

The relative luminescent efficiencies of the substitution screens used in both the laboratory tests previously discussed and in the field test were obtained by exposing a substitution screen and the "standard" Radelin FGC screen to the same X-ray beam and obtaining photometer readings from both. The ratio of the photometer reading of the substitution screen to the photometer reading of the "standard" screen was defined as the relative luminescent efficiency of the substitution screen. Four such efficiency values were determined for each substitution screen, with each efficiency being obtained at a different exposure rate. The exposure rates were 0.67 R/min, 1.26 R/min, 1.95 R/min, and 2.50 R/min corresponding to current settings of 1 mA, 2 mA, 3 mA, and 4 mA. The X-ray machine was operated at 80 kVp for all of these measurements.

The variation of the relative luminescent efficiencies of the substitution screens with variation in exposure rate was not thought to be significant, approximately $\pm$ 3 percent. A further test was performed on a screen to determine if its relative luminescent efficiency would change with variation in peak kilovoltage if the exposure rate were held constant. The exposure rate was held at 1.7 R/min, while relative luminescent efficiency values were obtained at 60 kVp and 90 kVp. It was found that the two efficiency values thus obtained were within less than one percent of each other. Based on these tests, it was concluded that the relative luminescent efficiency does not change significantly with changes in exposure rate or changes in peak kilovoltage, within the limits of normal fluoroscopic operation.

Table 8. Percent error in estimates of the relative luminescent efficiency of a test screen by five observers using the Visual Brightness Comparer

| Observer | Percent Error in Estimate of Test Screen's Relative Luminescent Efficiency | |
|---|---|---|
| | No dark adaption | 20 min dark adaption |
| 1 | +15% | +15% |
| 2 | +10% | + 5% |
| 3 | - 5 to 10% | -10% |
| 4 | + 5% | + 5% |
| 5 | -10% | -10% |
| | (- sign indicates an under estimate of light output) (+ sign indicates an over estimate of light output) | |

The conclusions that can be drawn from these two tests are that the observers could discriminate between two screens that exhibit a 20 percent or more difference in brightness with reasonable accuracy. The region between 5 and 15 percent difference in brightness seems to be a "decision" region requiring more judgment on the part of the observers. Consequently the accuracy in this region drops off. There seemed to be little difficulty for the observers to make the correct response with the Visual Brightness Comparer for those screens that had the same relative luminescent efficiency. From the results of the second test, it can be seen that four out of five observers could estimate the brightness of a screen to about + 10 percent. It is significant to note that some observers estimated high while other observers estimated low. In both of these tests dark adapting did not significantly increase brightness discrimination or reduce the percent error in estimating the brightness of a screen.

# APPENDIX C

## DESCRIPTION OF THE PHOTOMETER

The photometer used in the field test was designed and constructed by Mr. Emmet Murphy in 1962. It consists of three components; a fluoroscopic "standard" screen assembly, a photometer head, and a power supply-meter box (figure 7). The fluoroscopic "standard" screen assembly is used only when a photometer reading of the "standard" screen is being obtained. The assembly consists of bakelite backing, "standard" screen, and lead glass cover. This arrangement simulates the conditions under which the photometer reading of the test screen is obtained. The assembly weighs one pound and measured 6 inches x 6 inches. The screen area exposed is 2-1/4 inches x 2-1/4 inches. The photometer head contains an IP21 photomultiplier tube with twelve NE51 neon lamps across the dynodes to provide voltage stabilization. The photometer head has a 7/16-inch-diameter shutter opening. It weighs one and a half pounds and measures 3 inches x 3 inches x 5-1/2 inches. The power supply-meter box weighs six and one-half pounds, and measures 5 inches x 7 inches x 9 inches. It contains three 300-volt batteries which power the photomultiplier tube, and a flashlight battery which powers a small light for reading the meter in the dark. A 50-microampere meter is mounted on the face of the case. The photometer was not calibrated in absolute units for the field test since only comparative readings were of interest. However, it has a range of approximately 0 to 300 microlamberts. Figure 8 shows the photometer wiring diagram.

One of the concerns in assuring the validity of the results of the evaluation of the Visual Brightness Comparer was that the photometer give consistent readings for a given light source over a period of time. To test the consistency of the photometer readings, daily measurements were made, over a two week period, of the light produced by a fluoroscopic screen exposed at a rate of 2.4 Roentgens per minute. The mean photometer reading was computed, and the percent deviation from the mean value was plotted for each daily measurement. As shown in figure 9, the photometer readings showed an average variation of less than 1.5 percent with a maximum of 6 percent in one instance.

The exposure rate of 2.4 R/min was obtained from a General Electric Maximar-100, operated at 80 kVp and 3 mA. Three millimeters of aluminum were added, giving a measured half-value layer of 2.5 mm of aluminum. Measurements were made with a source to screen distance of 60 centimeters.

Tests were also conducted to determine the response characteristics of the photometer with respect to varying light levels from a fluoroscopic screen. The screen used in this test was a new DuPont CB-2. The photometer response was measured in percent full scale deflection and plotted as a function of the exposure rate being delivered at the fluoroscopic screen. The exposure rate was varied by holding the kV constant and adjusting the mA, and also by holding the mA constant and changing the kV.

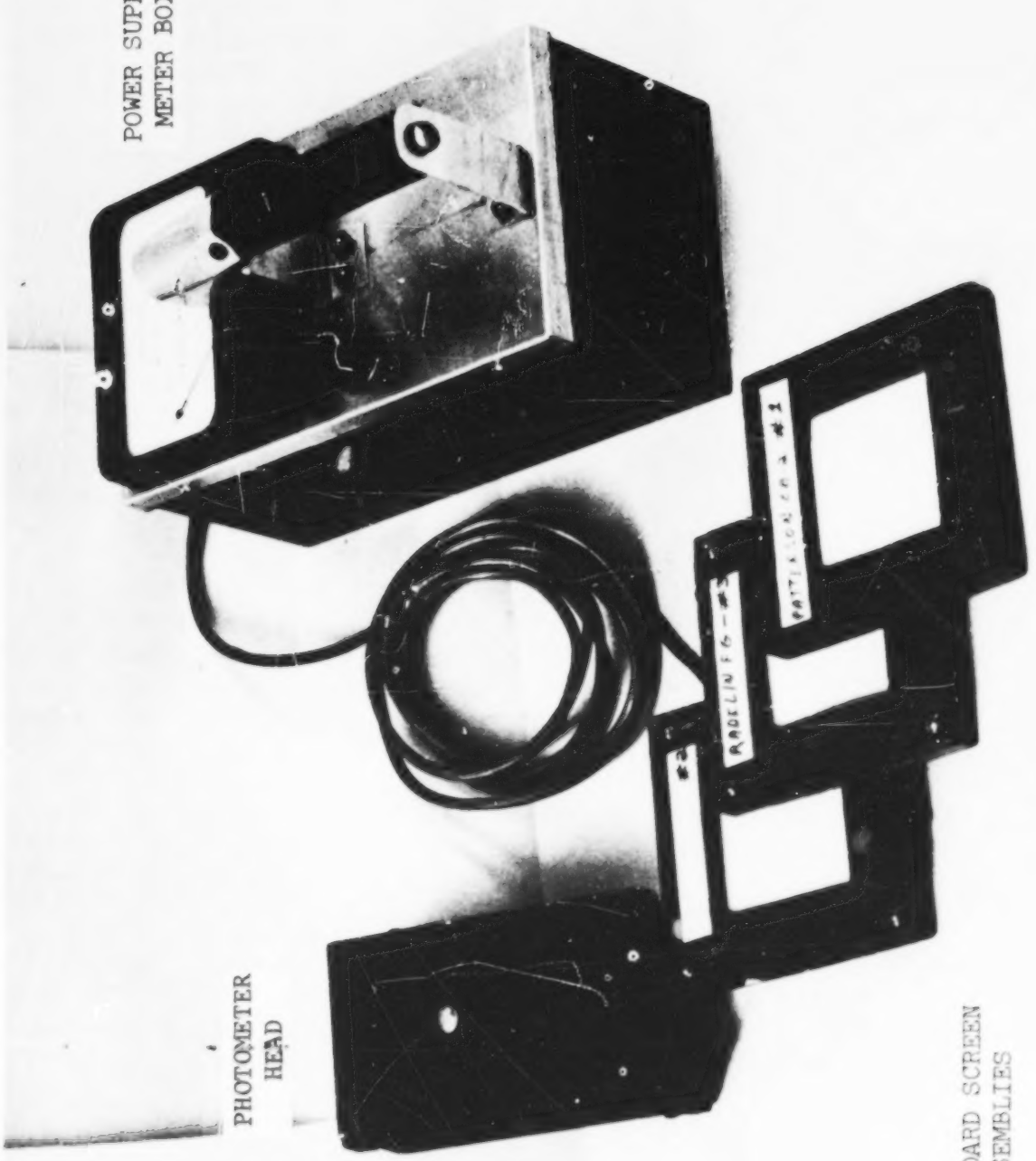


Figure 7. Photometer: photometer head, screen assemblies, and power supply-meter box

* U. S. GOVERNMENT PRINTING OFFICE : 1970 395-051 (70)

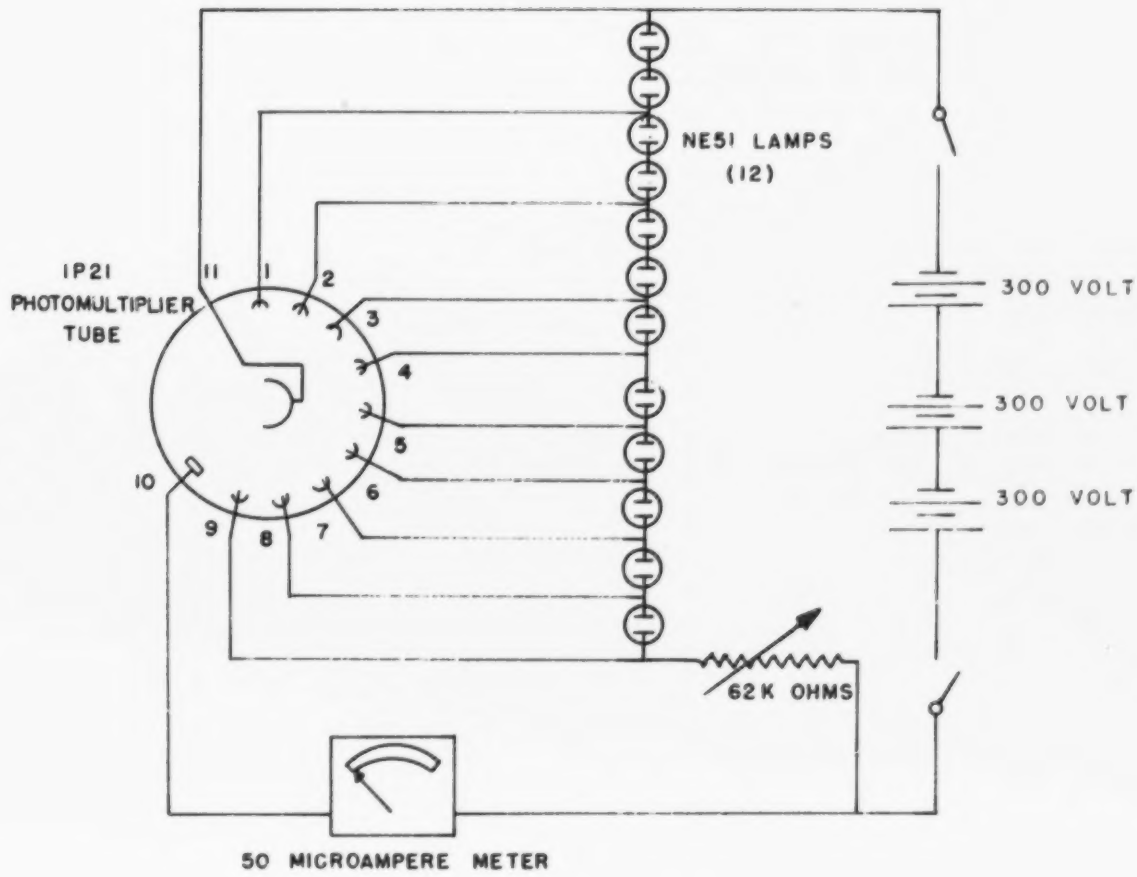


Figure 8. Photometer schematic

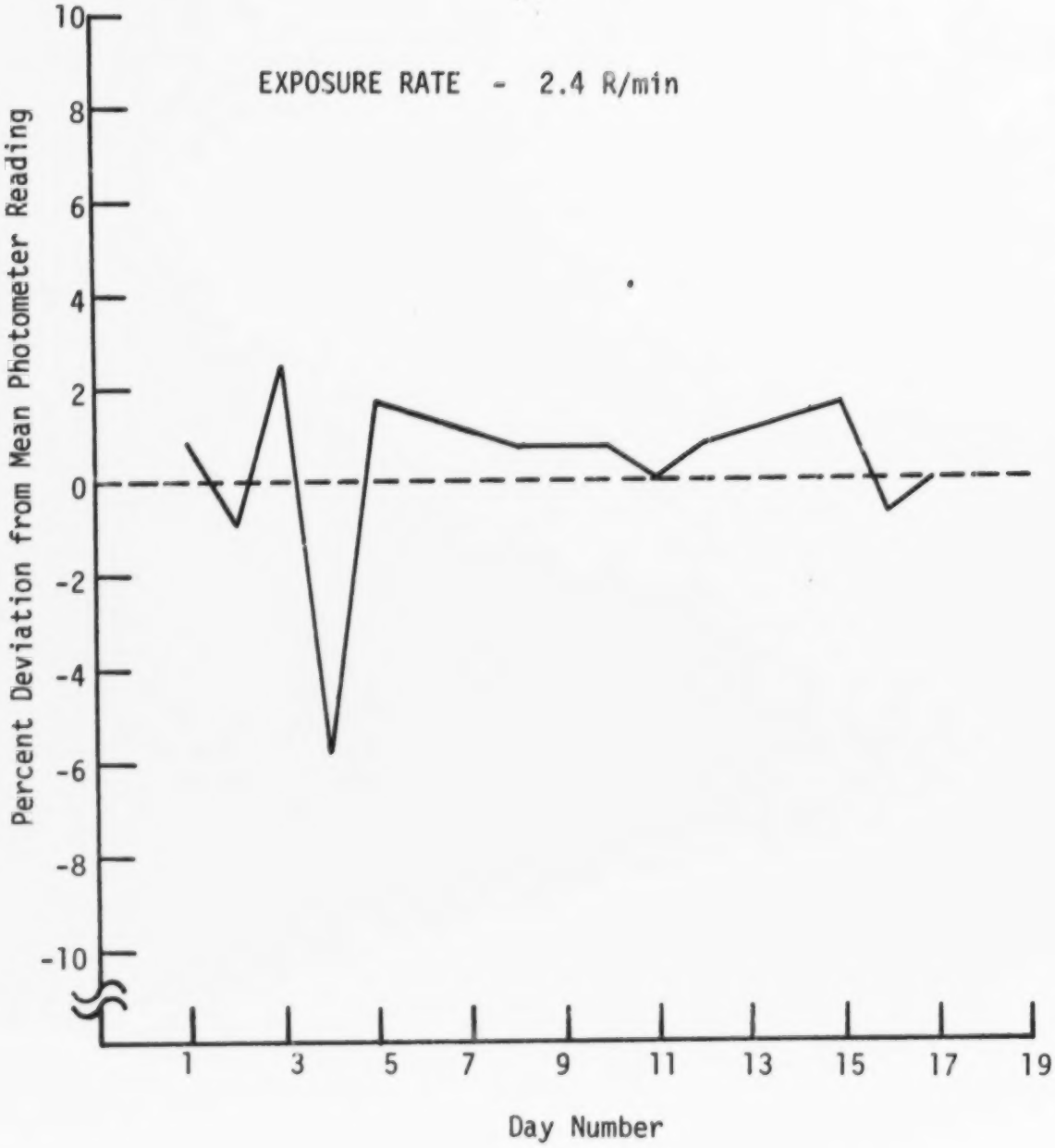


Figure 9. Percent deviation from mean photometer reading versus time

The experimental set-up was similar to that described for the measurement of photometer consistency with time except that a 1/8-inch piece of masonite was positioned in the beam at a distance of 35 cm from the X-ray source. The kV, mA, and measured screen exposure rates are shown in table 9 .

Table 9. Measured screen exposure rates used to determine photometer response characteristics

| kV | mA | Exposure Rate |
|---|---|---|
| 80 | 3 | 1.97 R/min |
| 80 | 4 | 2.51 " |
| 80 | 5 | 2.97 " |
| 60 | 4 | 1.32 R/min |
| 70 | 4 | 1.89 " |
| 80 | 4 | 2.57 " |
| 90 | 4 | 3.10 " |
| 100 | 4 | 3.98 " |

The results from this test, as shown in figures 10 and 11, indicate that the photometer responds linearly to the exposure rate at the fluoroscopic screen. The exposure rates used are typical of those experienced during the field test.

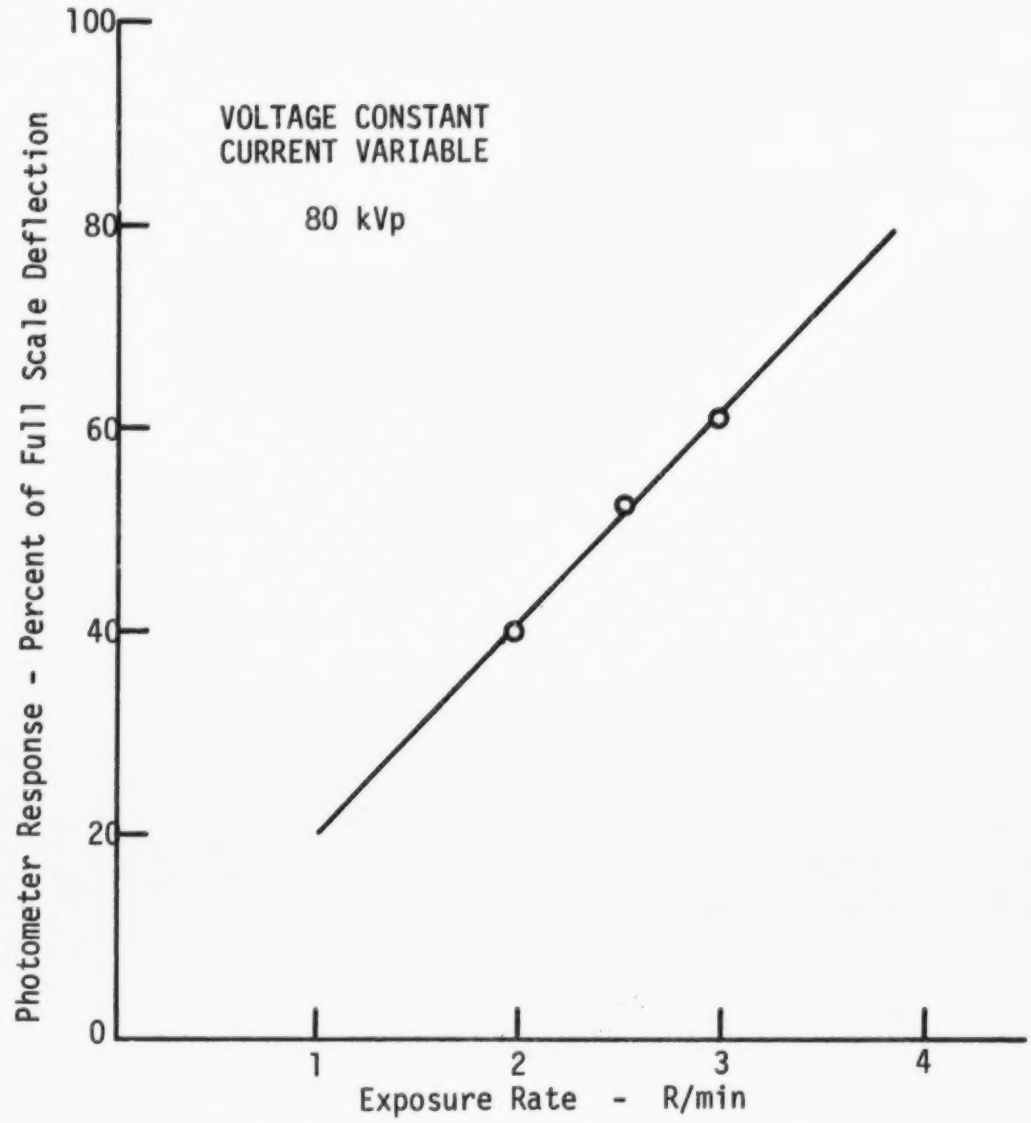


Figure 10. Photometer response versus exposure rate at constant kVp

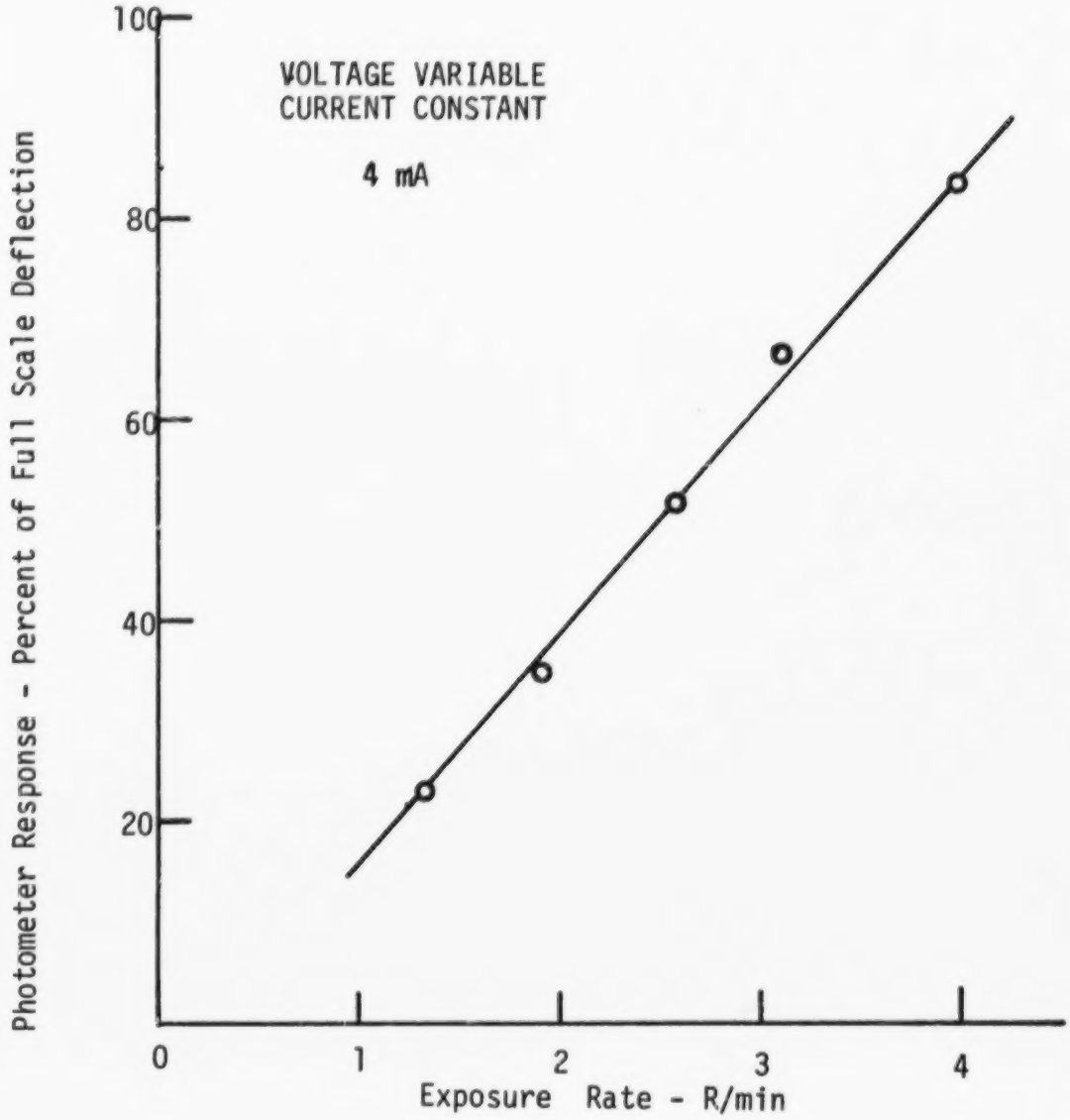


Figure 11. Photometer response versus exposure rate at constant mA

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DESCRIPTION AND EVALUATION OF A FLUOROSCOPIC SCREEN VISUAL BRIGHTNESS COMPARER - Accession No.
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KEY WORDS: Survey instrument, Fluoroscopic screens

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